Modern Image Processing for Homeland Security

Thomas Meitzler, Ph.D. and Mary E. Bienkowski
U.S. Army RDECOM-Visual Perception Laboratory (VPL)
Warren, MI 48397

The RDECOM-TARDEC Visual Perception Laboratory (VPL) was designed to evaluate the detectability of camouflaged vehicles in both the visual and infrared spectrum, assess computer simulated renderings of camouflaged vehicles and evaluate electro optical cameras and systems for homeland defense applications.

Modern image fusion technologies will allow the US Military to achieve the surveillance, security and detection applications needed in 21st century warfare. When combining information extracted from multiple sources, the fused result will provide more details, resulting in a superior battlefield advantage.

Some of the potential applications of image fusion and 3D displays for homeland defense are listed below. The VPL is actively working with various Homeland Security liaisons to locate programs to develop and apply these technologies.

- Concealed weapon and mine detection using sensor fusion and edge enhancement along with passive infrared and/or millimeter-wave multi-band imagery.
- Close-proximity wrap-around fusion vision system for airplane passenger cabins terrorist identification.
- Surveillance vehicle with wrap around enhanced vision and concealed weapon detection for peace keeping operations.
- Aerial unmanned robotic surveillance.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **04 FEB 2005**	2. REPORT TYPE **Journal Article**	3. DATES COVERED **04-02-2005 to 04-02-2005**

4. TITLE AND SUBTITLE **Modern Image Processing for Homeland Security**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Thomas Meitzler; Mary Bienkowski**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC ,6501 E.11 Mile Rd,Warren,MI,48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER **#14604**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. Army TARDEC, 6501 E.11 Mile Rd, Warren, MI, 48397-5000**	10. SPONSOR/MONITOR’S ACRONYM(S) **TARDEC** 11. SPONSOR/MONITOR’S REPORT NUMBER(S) **#14604**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The RDECOM-TARDEC Visual Perception Laboratory (VPL) was designed to evaluate the detectability of camouflaged vehicles in both the visual and infrared spectrum, assess computer simulated renderings of camouflaged vehicles and evaluate electro optical cameras and systems for homeland defense applications. Modern image fusion technologies will allow the US Military to achieve the surveillance, security and detection applications needed in 21st century warfare. When combining information extracted from multiple sources, the fused result will provide more details, resulting in a superior battlefield advantage.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

• Millimeter-wave (mm-wave) using passive sensors to detect hidden objects – no irradiation of subject

• Integration of 3-Dimensioanl (3D) visual images and mm-wave to increase visibility and clarity of the image

• 3D display technology could be deployed for use at existing airport search stations, or imbedded in walls; the technology unobtrusively scan passengers and other airport personnel

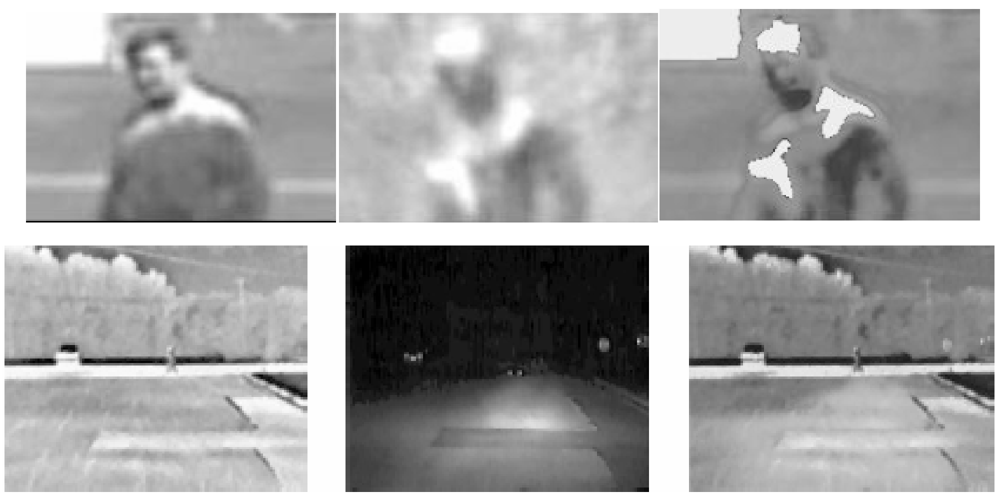

Fig. 1: *Visible Image, mm-wave image, and fused image of concealed weapon with Fuzzy Logic (Top Row: left to right respectively); Infrared, visible, and fused image of a pedestrian in the road (Bottom row: left to Right respectively)*

The same algorithms that are used for fusion of multiband imagery for mine detection can also be used for the purpose of concealed weapon detection. Fig. 1 illustrates how fuzzy based image fusion can be used to segment areas of an image that may show a concealed weapon. The VPL has been working with Wayne State Univ. and Ethereal Technology in Ann Arbor to apply auto stereoscopic technology and image fusion to the problems of detecting people carrying weapons, also with 3D baggage inspection at airports, and crowd surveillance at large public facilities. The auto stereoscopic display as it exists in the VPL is shown below in Fig. 2. The unique and important features of this display is

that it is not dependent on users wearing goggles or glasses and is a high resolution display. A 3D image is formed by the brain fusing a left and right image as it does from the left and right eye. Using image fusion in concert with 3D displays has the potential to greatly improve the detection of concealed objects.

3-Dimensional Display and Stereoscopic Imagery:

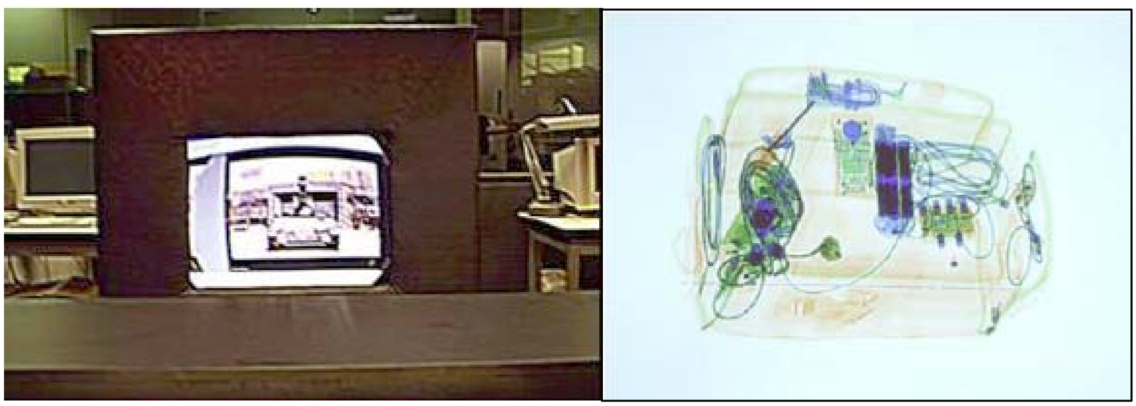

Fig. 2: *3D Display of Ethereal Mirror and 3D Image of X-Ray scanned package (left to right respectively)*

With the current elevated concern over security, VPL engineers have been investigating using 3D displays to increase the through-put scanning efficiency and accuracy of detection of concealed explosive devices in packages. Fig. 2 demonstrates the prototype 3D display that can project 3D images from a stereoscopic pair of images. A pair of X-ray images, such as the one of a package shown below, that are obtained from a conventional X-ray scanner such as is used at the TACOM receiving dock, can be presented in 3D to observers without the use of special viewing goggles.

It has been estimated that failures in advanced man-machine systems can be attributed to "human error", and increasingly to loss of operator situational awareness (SA), and may be as high as 75%. Three dimensional displays will increase SA by allowing us to see

information collected by sensors in a natural environment as opposed to planar images. There are a number of mirror systems which form a real three dimensional image in space of an object in a position which is well separated from the object. One of the major parts of the stereoscopic display used in the VPL is the spherical concave mirror. A spherical mirror can magnify the size of the object being displayed as shown in Fig. 2.

There is a need for technology to scan packages and use this 3D system to reduce illegal transport of weapons and potential threats on U.S. soil. This display can be applied to crowd surveillance and screening at public access points. In these times of increased concerns about terrorists and passengers carrying concealed weapons or other harmful items, sensor fusion and 3D displays could be of benefit in alerting guards to potential dangerous passengers. Combining sensor fusion with a 3D display could also improve the recognition rate of guards using cameras that scan crowds for people that are listed in a known terrorist database. We believe that implementing volumetric visible and IR images will improve the recognition rate, because it will provide a more detailed 3D image or thermal properties versus only a 2D visible image of possible terrorization.

Panoramic Image Fusion (PIF) System:

Fig. 3: *Concept of panoramic image fusion for ground vehicles; Ford Lincoln Navigator with PIF system (left to right respectively)*

The VPL team and Ford Laboratories are testing and beginning the technology insertion of a vision system called Panoramic Image Fusion (PIF). Applications of this system range from peace-keeping operations in Iraq, homeland defense, surveillance at boarders, early warning passive detection of threats, as well as medical telepresence. The vision system is mounted on to the front and rear of the vehicle and provides day and night panoramic imaging by fusing the visible and infrared video from multiple cameras in real-time. The system uses commercial off-the-shelf (COTS) video cameras and imaging boards. Combine imaging sensor fusion capability with the ability to look anywhere around the vehicle and you have what the Army calls situational awareness. Why is more than one type of sensor required? Because infrared cameras give increased night vision capability and visible sensors are of little to no use at night or in areas with poor lighting. Even in the well-lit areas, night vision technology provides a benefit to safety by making it easier to detect camouflaged insurgents. In daylight, panoramic image fusion can be used to detect an individual in a crowd who has recently fired their weapon, due to the heat generated by the weapon as seen through clothes by the imaging sensors. Fig. 1

depicts a faux scenario of a heated weapon underlying an article of clothing of a person surrounded by a crowd of civilians.

The benefit of panoramic image fusion to the crew of an armored vehicle is that it provides situational awareness prior to egressing from the vehicle. A soldier or officer in a closed vehicle can use this technology to pan and zoom around the vicinity of the vehicle and therefore have knowledge of possible locations of potential combatants. The major benefit is that the scene can be interpreted much more quickly and accurately, thereby increasing the survivability of the soldier. An Example of the image fusion process for driving safety is shown in Fig. 1, where a pair of infrared and visible road crossing scenes that were fused using the method of Fuzzy Logic.

VPL Status:

In FY 04 the VPL's research aimed at homeland defense and the Global War On Terrorism (GWOT) was aired on a local television channel, hosted by Ms. Marcella Lee. The segment discussed the panoramic image fusion system being developed for tactical vehicles as well as a novel 3D imaging technology that could be used to scan crowds at entrances to public structures. The VPL was also highlighted on the History Channel's recent series on Stealth on Land series. The use of the lab for camouflage assessment was described and CAPT Hetzel showed how a soldier takes a camouflaged vehicle perception test in the VPL.

As mentioned in the key research areas above, the VPL has developed a panoramic image fusion system for increasing the situational awareness of soldiers in Iraq, National

Guardsmen and patrol officers at home. This technology has been shown to many PM's (Stryker, LAV, Tactical Vehicle, HET) and all who have seen it want it on their vehicles for in-theatre testing. The only problem at this time is funding to supply the fleet of vehicles that various customers are asking for.

Maintaining situational awareness, dynamic surveillance, and target development is important for the soldier. This task will be accomplished through image sensor acquisition, data fusion and 3D visualization. The implementation of the integrated image system will support real-time SA for Homeland Defense by providing images of vehicles with IR signatures.

Biographical Sketch:

Thomas J. Meitzler received his B.S. and M.S. in Physics from Eastern Michigan University and his Ph.D. in Electrical Engineering from Wayne State University in Detroit, Michigan. From 1988 to present he has been a research engineer at the for the Survivability team of the Research Business Group (RBG), at the Research Development and Engineering Command (RDECOM) in Warren, Michigan. He has published many papers on the application of fuzzy logic, statistical methods to infrared and visual detection methods, and co-written encyclopedia chapters on image processing and infrared imaging. He has worked on the validation and verification of infrared and visual sensor simulation and atmospheric propagation models for UNIX and Windows based computers. Dr. Meitzler has applied detection testing and modeling methodologies to military ground vehicles, concealed weapon detection and remote surveillance. His research interests include sensor fusion, non-destructive testing, functional magnetic resonance, 3D- imaging technologies and high fidelity photo-simulation.

Mary E. Bienkowski is a Mechanical Engineer for the Visual Perception Laboratory (VPL), for the Survivability team of the Research Business Group (RBG), at the Research Development and Engineering Command (RDECOM) in Warren, Michigan as of 2003. She received her B.S. in Mechanical Engineering and is currently pursuing her M.S. in Engineering Management, both from Oakland University in Rochester, Michigan. Her most recent research development involves image fusion, camera response testing, and threat assessment through stereoscopic imagery for on-going Homeland Security collaboration. Additional research includes improvements to the NASA ice-debris inspection system for the external shuttle tank, and analysis of probability of detection for stealth assessment using functional magnetic resonance imaging (fMRI), with Columbia University.